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ABSTRACT

TRON, a Walt Disney Production, is the first feature film to make extensive use of computer-generated animation. Information International, Inc. (III) and MAGI-SynthaVision were selected to do these scenes for the film. At the start of TRON, III had just finished production on the film LOOKER for the Ladd Company and had begun a shift in emphasis toward Production from Research and Development in the field of computer graphics.

The TRON production process for the computer-generated animation done at III involves creating data bases of objects and their environments as well as choreographing the action in each scene. TRON for the first time requires high quality computer graphics in quantity. A lot of lessons are learned from this endeavor.

The path to completion developed at III involves: geometric modeling, selection of colors and shading parameters with a color monitor refreshed from a frame buffer, wedging around these parameters on film, setting key frames for scenes in vectors, choreographing animation within a programming environment, making vector motion tests, and combining all these efforts into the final shaded film. Along the way debugging and enhancement of software and hardware maintenance play an important role.

INTRODUCTION

TRON is the product of a time when computer technology is a new artistic medium. Computer resources for the purpose of making pictures are scarce. Researchers in the field tend to associate with academic institutions or the Defense Department. In the decade of the 70's superstar status was part of our culture and computer graphics had its own. In many cases a picture was the effort of only a few individuals with resource accessibility.

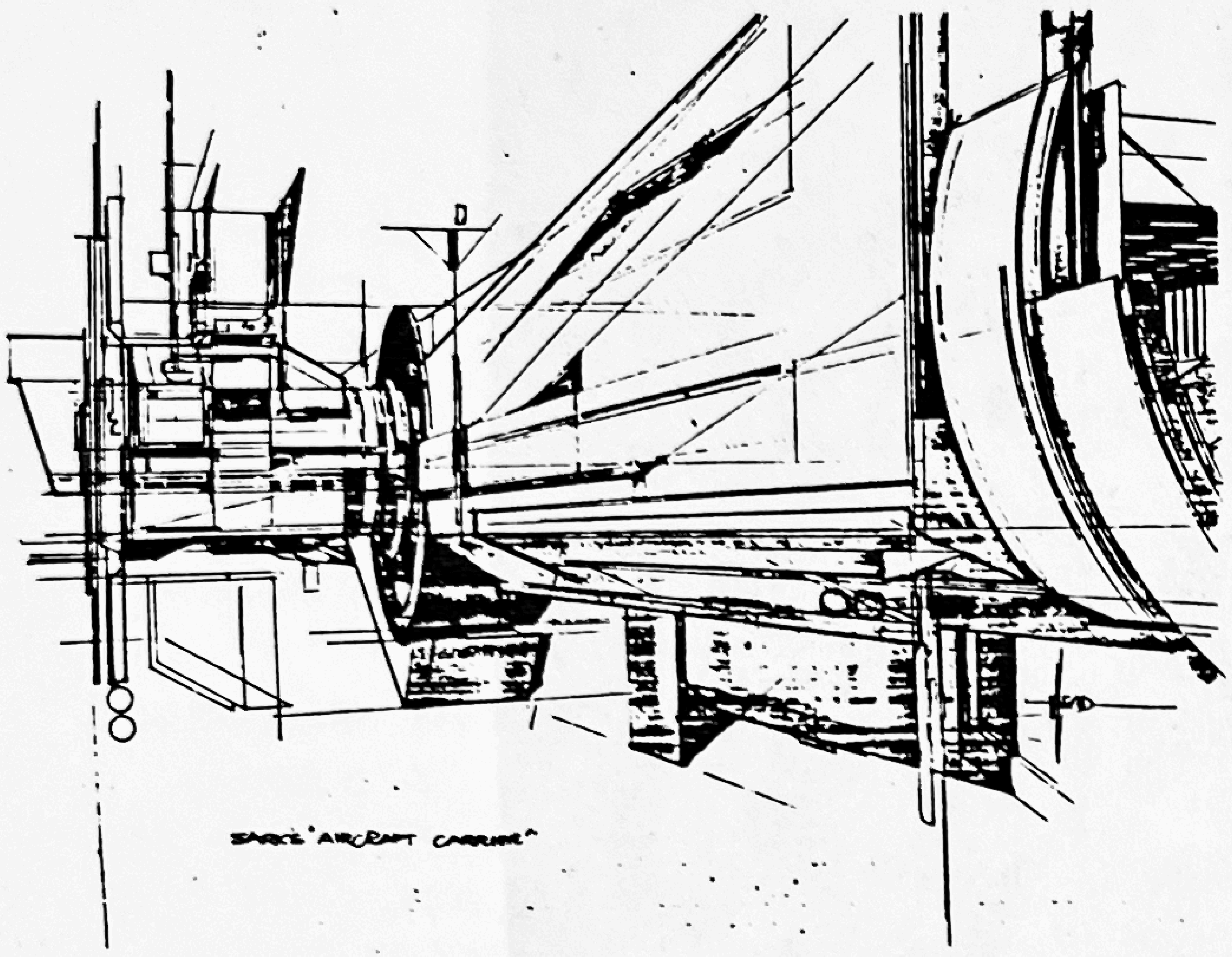
In many ways the decade of the 80's is starting out the same, but more emphasis in our culture is being placed on cooperation and team work. In order to complete a project the magnitude of TRON more than a few individuals are required. At III an ensemble of individuals with diverse talents have come together to aid in the making of TRON. The many steps involved in creating totally new environments and completeing scene after scene requires the synchronization of many skills.

In the story of TRON the Master Control Program is hostile to users. A great deal of user hostility has yet to be designed out of computer graphics systems. At III the computer systems typified the MCP's philosophy creating a tremendous challenge for the user. The Disney adventure that is shown in cinemas involves an equally impressive and trying adventure in its making.

GEOMETRIC MODELING

Geometric models are made based on sketches provided by Disney artists. Figure 1. shows Sark's carrier in a sketch by Syd Mead. Disney hired some extrordinary artists for visual concepts. Syd Mead designs futuristic art. Jean "Moebius" Giraud is a French comic artist. And Peter Lloyd's airbrushed illustrations have a highly polished look.

From these sketches creative directors at III prepare blueprints showing two orthogonal views of an object. The prepared drawing is then taken to the digitizing tablet for encoding. Art Durinski's drawing of Sark's carrier appears in Figure 2.



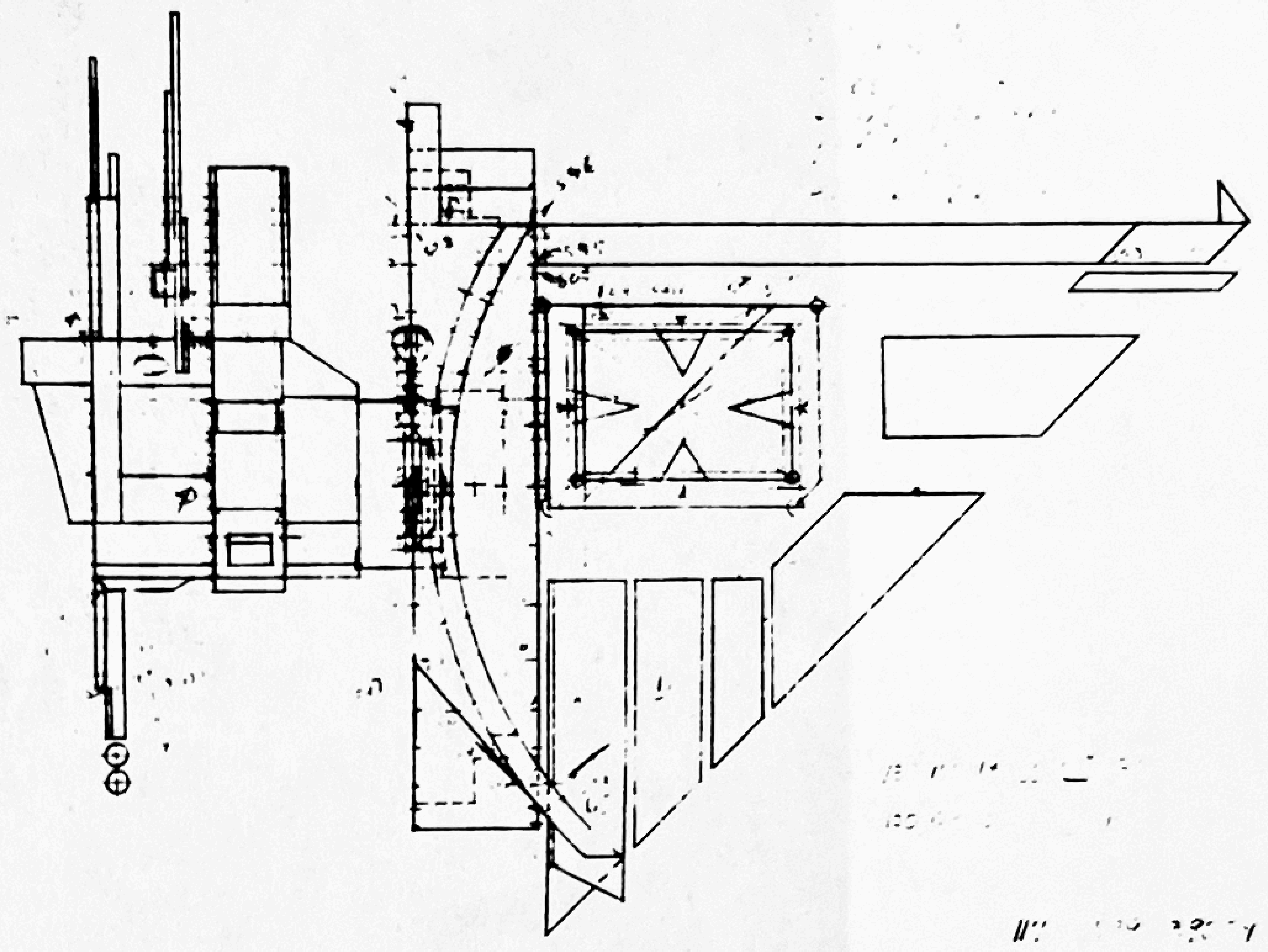


Figure 1. Sark's Carrier by Syd Mead

Figure 2. Drawing of Sark's Carrier

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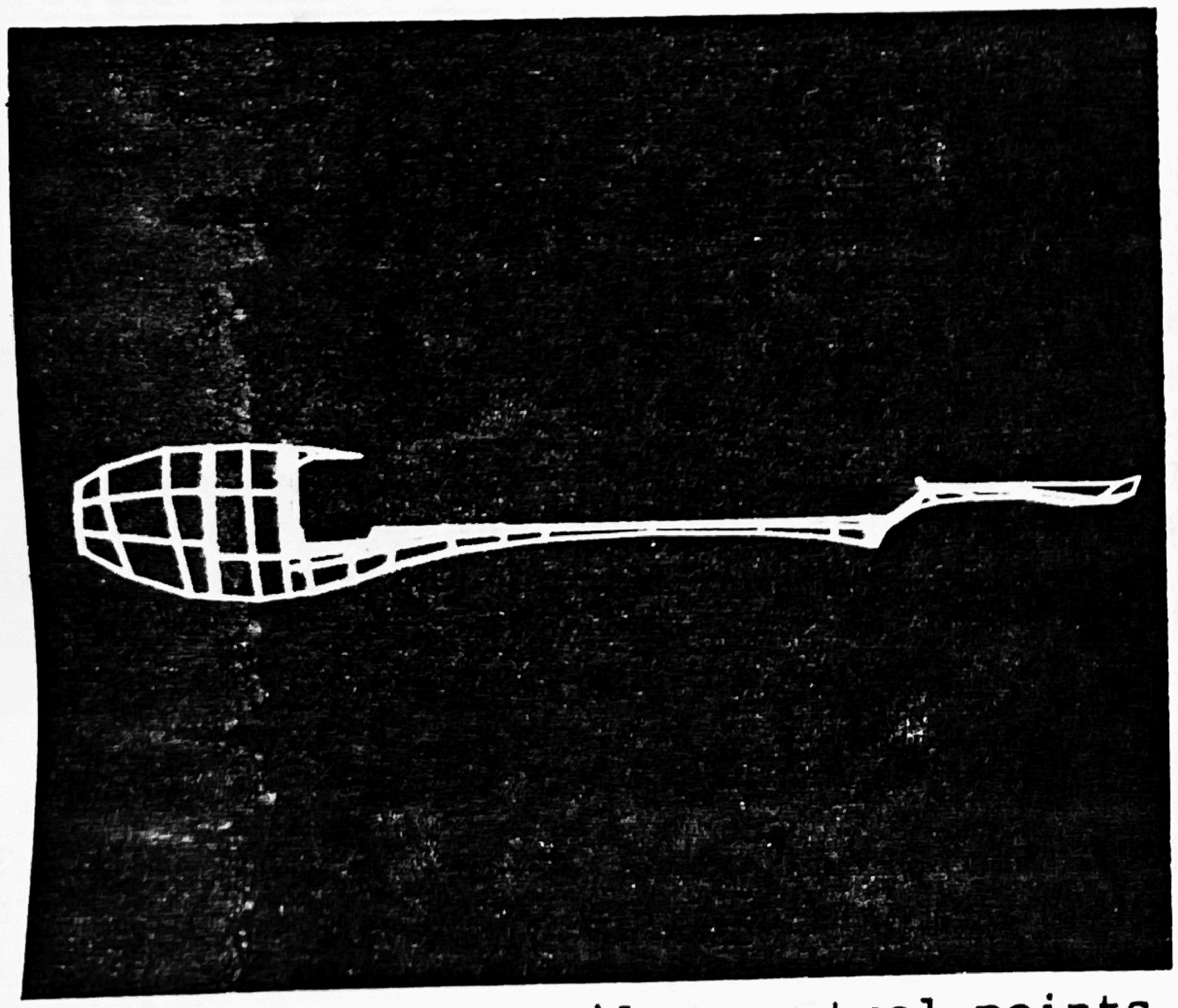
At the encoding station one cursor is used to locate the z coordinate of a point on one view and the other cursor locates the point x and y coordinates on the other view. Points are grouped together to form edges and edges linked to form polygons. To aid the creative director the result can be viewed from any angle on a vector display as the object is being encoded.

The Solar Sailer was made similarly except that Larry Malone encoded a set of b-spline control points, Figure 3., instead of polygons. From this data a smooth surface was created mathematically, Figure 4., requiring less effort than encoding the shape as polygons.



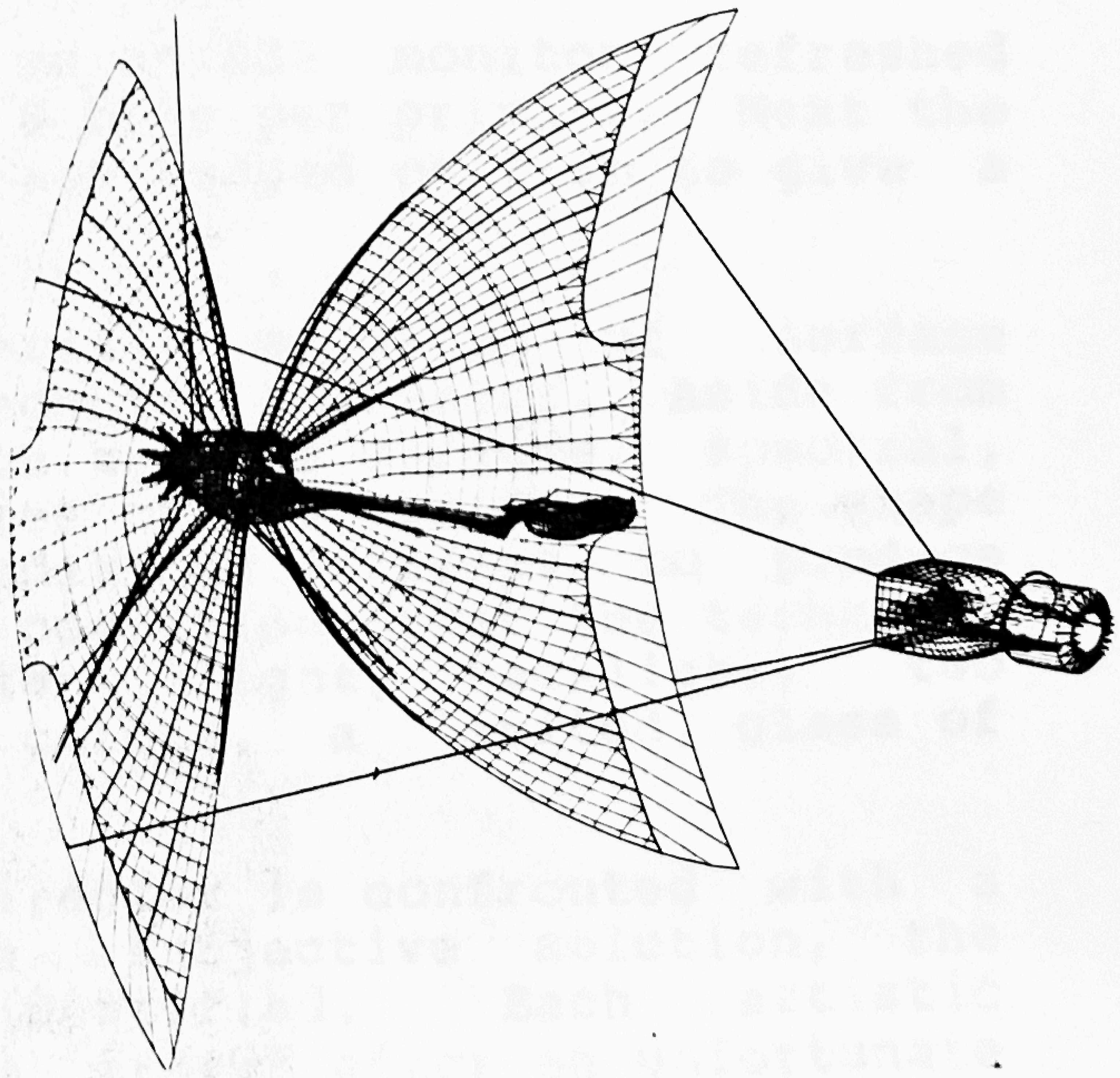


Figure 3. Solar Sailer control points

Figure 4. Vector Solar Sailer

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Regular shapes are often easier to make algorithmically. The buildings in one segment of the movie were created by Jeremy Schwartz with a geometric editor, Figure 5. Quadric shapes were generated with a program written by Bill Dungan to be used as orbiting satellites in the MCP domain. And the regular sea floor was made by Craig Reynolds using ASAS.

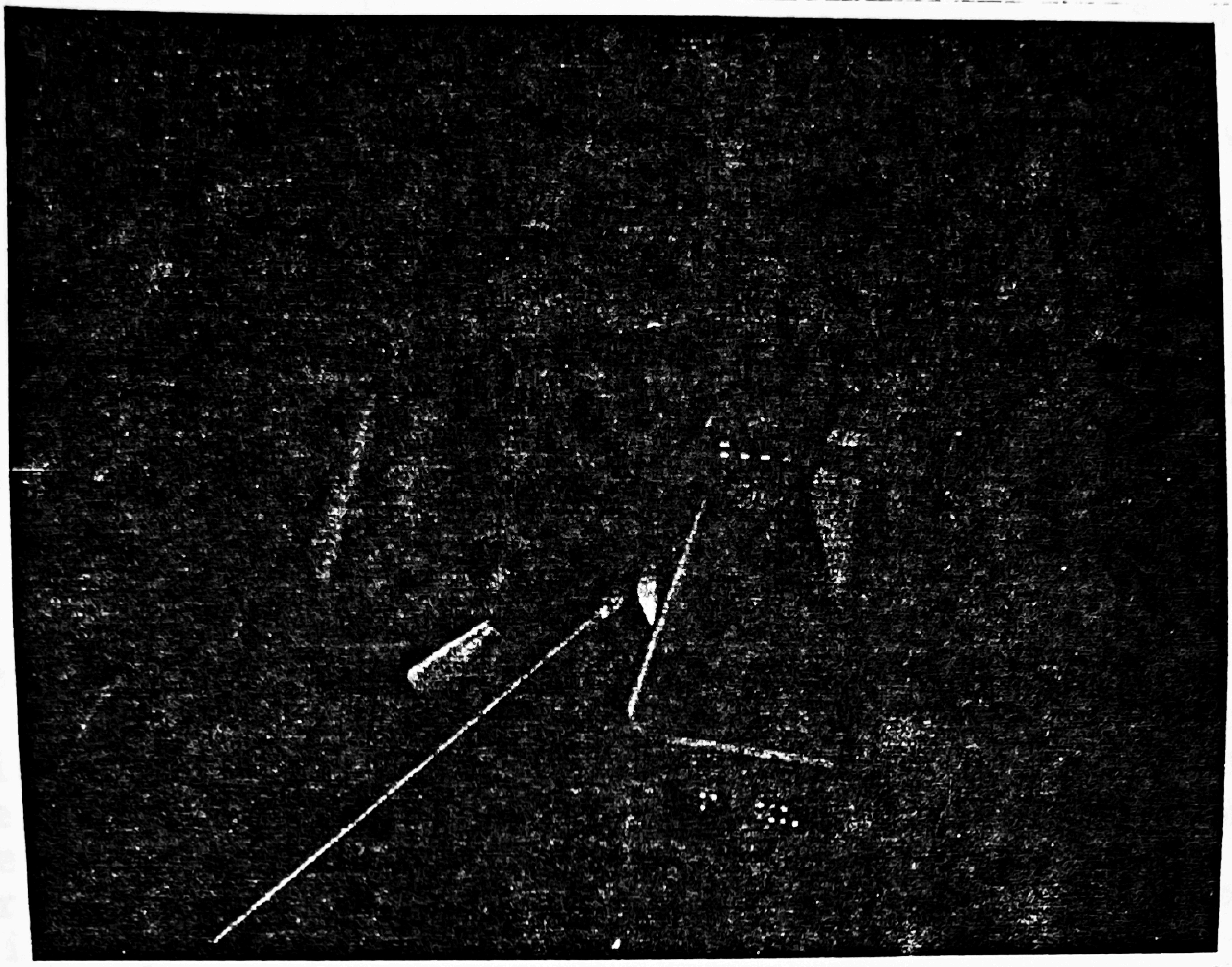

Figure 5. Solar Sailer through buildings
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Small details give a large object a sense of scale. The effort involved in making a detailed object can take over a month. A simple computer object may be a major accomplishment for the person programming it but it still looks like a simple computer object. The look that is necessary to compete with other quality special effects processes must look special. Computer models must be refined so that any identifiable computerishness is not distracting.

COLOR SELECTION

The color of each object is first set on an RGB monitor refreshed from a 1024 X 1024 frame buffer with 6 bits per primary. Next the color and relevant shading parameters are wedged on film to give a choice of looks.

To simulate a wide range of materials a group of surface characteristics are defined by the technical director. Aside from the surface color these characteristics set the diffuse, spectral, transparence and reflectence properties of the surface. The shape of a surface and the environmental conditions interact to produce the appearance. The environmental conditions that the technical director can specify are the ambient light, backlight, two positionable light sources, their colors, a limited class of reflections and depth cueing.

To get a certain look the technical director is confronted with a multi-dimensional problem with a subjective solution, the parameters of which were just identified. Each artistic composition must ultimately resolve itself after an unfortunate exercise in catastrophe theory. The path from a given set of parameters to "ten percent more blue" for instance , as our creative director Richard Taylor is apt to request, is fraught with discontinuities and adverse cross terms poorly understood even after much experience. Linear reasoning is a hard habit to break.

At approximately five minutes per frame, the speed it takes to compute, the technical director has an incentive to pick the final parameters on the first few tries, or conversely to be satisfied with a minimum of changes. Dealing as we are with Disney, artistic considerations prevail, and the resulting color selection process is quite time consuming. Ultimate authority in setting colors resides in our creative director Richard Taylor who is also the supervisor of Special Effects for the entire movie.

Compounding the visual feedback problem is the fact that the color gammut of a monitor is not the same as the color gammut of film. Once a general look is decided upon from the color monitor, tests are shot on film. The term "wedge" is borrowed from optical printing which we use to mean varying the contrast of the image on film. The theory behind "wedging" is successive approximation. Anything beyond linear wedging is prohibitive and wedging a single parameter is often inadequate. In practice the monitor colors are set, then a wide range of a single parameter such as ambient light is wedged and fixed, and lastly a small range of a second parameter is wedged.

A flexible set of parameters is needed for a wide range of looks but clearly a better human interface is required for the task of color selection than currently exists. One blessing associated with feature films however is that once the shading parameters are fixed for one scene subsequent scenes using the same elements become easier to set. The final shaded rendition of Sark's carrier is pictured in Figure 6.

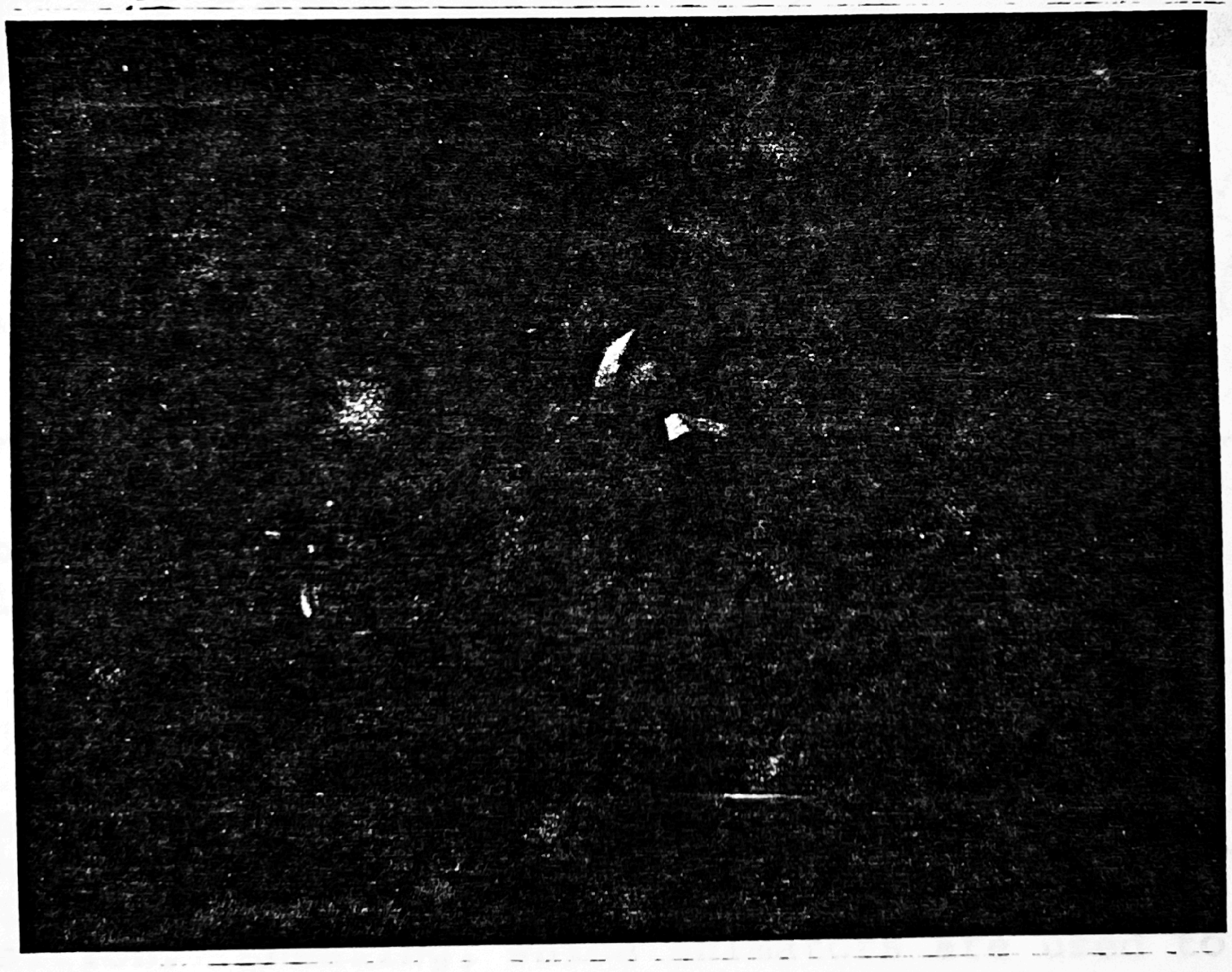

Figure 6. Sark's Carrier

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CHOREOGRAPHY

Key frames of each scene are set up with animators in vector form and then vector motion tests are made to verify the choreography. Disney animators Bill Kroyer and Jerry Rees take the timing of each scene and break out the key moments of action. The major composition of these frames are storyboarded to provide guideance for the technical director. At first the animators produced drawings as they imagined the frames would appear including shading. Schematic diagrams proved more useful than anticipated views because the computer often disputed the accuracy of the animators imagination. The computer is more accurate at perspective and shading.

The intention of the storyboard is to give position and timing. The animators were quick to grasp the utility of the faster ability of the computer to display vector images. The storyboards then became quick and dirty sketches of the major object positions at key frames. Often a better approach was to map out the action on a grid. Two views of a storyboarded scene are shown in Figure 7.

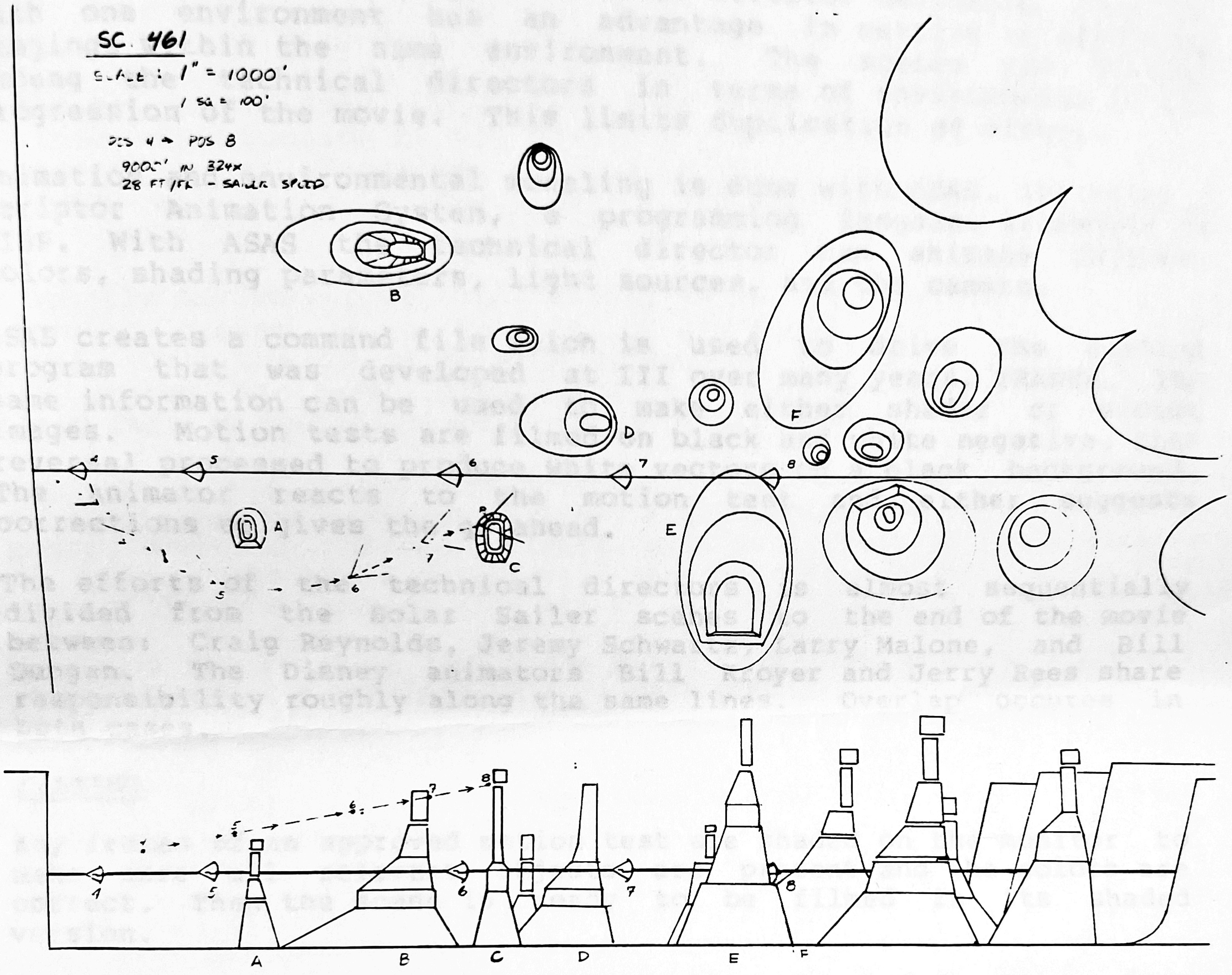

Figure 7. Storyboard of Solar Sailer through buildings
©Walt Disney Productions

An animator sits beside the technical director as he interactively positions the camera and objects. A dialogue of intention and feasibility is carried out until the animator is satisfied with the scene composition. Cheating, which animators are used to, is more difficult with the computer, but not impossible. The computer is a new tool with its own ways. The goal is a favorable audience response. No computer can judge that and logic need not be of any concern. The sense of staging and timing that animators posess is an asset that the computer is not apt to usurp.

The computer has extremely flexible capabilities for making pictures. Everything is always in focus for the computer camera, the viewing angle can be anywhere from 0 to just less than 180 degrees, a continuous zoom in angle can be used instead of trucking the camera position, and objects can interpenetrate the camera position. Computer sets are capable of being taken apart like physical breakaway sets however they take no more space than a magnetic tape.

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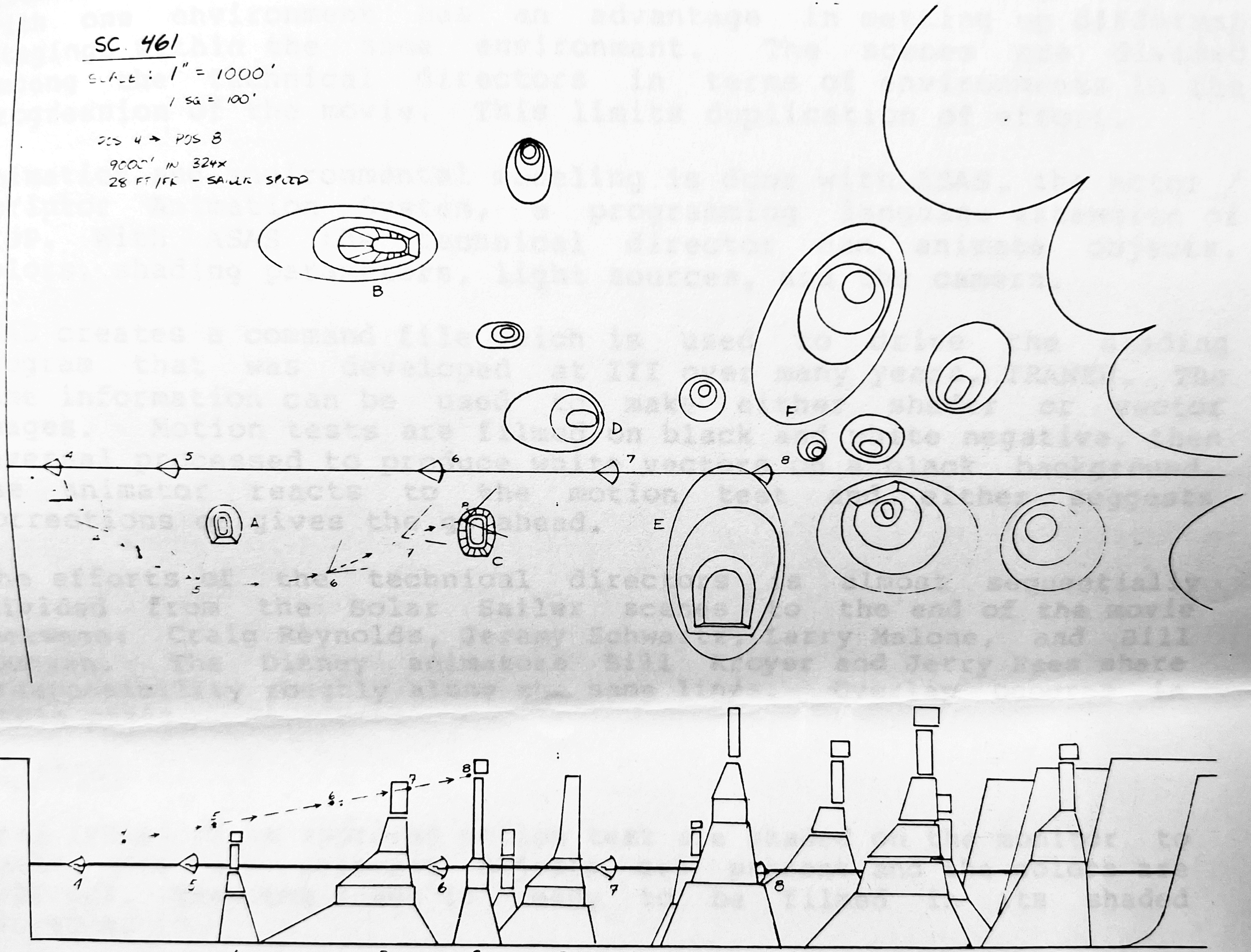

Figure 7. Storyboard of Solar Sailer through buildings
© Walt Disney Productions

A certain amount of preparation is required by the technical director before the key frames of a scene can be set. An animation language is used at III. If an object is to exhibit motion more complicated than translation it often saves time to imbody the object with the versatility it needs to make the technical director's task easier. Scenes with similar motions can benifit from earlier work. A single technical director becomming familiar with one environment has an advantage in setting up different stagings within the same environment. The scenes are divided amoung the technical directors in terms of environments in the progression of the movie. This limits duplication of effort.

Animation and environmental modeling is done with ASAS, the Actor / Scriptor Animation System, a programming language extension of LISP. With ASAS the technical director can animate objects, colors, shading parameters, light sources, and the camera.

ASAS creates a command file which is used to drive the shading program that was developed at III over many years, TRANEW. The same information can be used to make either shader or vector images. Motion tests are filmed on black and white negative, then reversal processed to produce white vectors on a black background. The animator reacts to the motion test and either suggests corrections or gives the go ahead.

The efforts of the technical directors is almost sequentially divided from the Solar Sailer scenes to the end of the movie between: Craig Reynolds, Jeremy Schwartz, Larry Malone, and Bill Dungan. The Disney animators Bill Kroyer and Jerry Rees share responsibility roughly along the same lines. Overlap occures in both cases.

FILMING

Key frames of an approved motion test are shaded on the monitor to make sure all relevant objects are present and the colors are correct. Then the scene is ready to be filmed in its shaded version.

One good practice is to maintain a backlog of shaded shots which are ready to shoot. Another good practice is to shoot key frames of each scene before commitment to the full blown run. The second of these practices was the first to go unheeded. In our efforts we shot first and asked questions later, sacrificing the caution to speed. If enough care is taken in setting up the animation scripts obvious errors can be avoided. Previewing representative frames on the monitor helps to catch defects before filming.

BACKGROUND STILLS

Background stills are shot at III on 4x5 Ektachromes to be composited with live action. The background still is enlarged to the cel size, 16x20. The film grain of a 35mm frame is apparent if it is processed in this way making it unacceptable. The background is composited by Disney with the other elements.

Many of these stills require matching critical edges on the live action set. For this often difficult task the edges in the frame are encoded from the cel. This information is used as an overlay for an operator trying to line up the camera position on the Tektronix. The bulk of this work was done by Jeremy Schwartz and Art Durinski.

SOFTWARE AND HARDWARE MAINTENANCE

Responsibility for software is individually allocated. When a bug is discovered the responsible programmer receives a complaint. A measure of how well any group interfaces with each other is the speed with which these bugs are fixed. In practice at III the response time is fast and delays are infrequent.

Object tweaking programs interfaced to a Tektronix storage tube terminal are written by Larry Malone in SAIL, the Stanford Artifical Intelligence Language. ASAS is written by Craig Reynolds in LISP, an expansion of his master's thesis from MIT. TRANEW, the new transparency algorithm, for making shaded images is written in FORTRAN and assembly languages. It is enhanced and maintained by Bill Dungan.

Aparently hardware problems are inevitable. The reliability of a computer system is a measure of the speed with which it can be fixed. Over the course of TRON production the reliability of the III system increased largely due to the heroic efforts of the III Field Service operation and especially Jim Rapley.

Complaints have become less frequent. Most of the glaring bugs were discovered and exterminated early during the filming. It is possible that no shading artifacts will be evident to the audiences of TRON. Those that we detected were corrected. Our plan is that any artifacts we can not fix are to be sold as system features to Disney. We have not resorted to this tactic. But in the final analysis the story of TRON takes place in a video environment where raster artifacts are just another part of life.

SUGGESTIONS FOR IMPROVEMENT

In the throes of production many needed improvements appear obvious. However, the amount of time available during production is tremendously limited. When judging each phase in terms of speed and present technology we identified faster methods than we are using. A real-time interactive vector display would be very useful for setting key frames, motion tests, and aligning background stills.

Many hidden surface algorithms compute the colors within the program main loop. For wedging, the geometry of the scene remains constant and only the object shading parameters vary. Identifying which surface is in front can be separated from shading the image and save considerable time in color selection. Often only a small portion of a frame is of concern. If a frame buffer is used only that small portion, identified by its objects, can be updated saving the time it would take to recompute everything.

Creating a computer-generated image can lose some of its glamour when it has to be repeated over and over again to get the colors perfect. With the advent of home computers with graphics capabilities the future does not look as bleak as we might suspect. Children with a lot of experience gained by playing with graphics may grow up with an intuitive grasp for what we now consider tedious and frustrating.